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HAZARDOUS AREA CLASSIFICATION FOR BIOMASS

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Abstract: Operators of facilities using biomass as a fuel must comply with the Dangerous Substances and Explosive Atmospheres Regulations (2002) (DSEAR). A key requirement of this legislation is that areas where a flammable atmosphere could arise are demarcated into zones. Traditional guidance on zoning or Hazardous Area Classification for dusts has not kept up to date with the latest technology and theories on dust explosion science.

This project identified a number of key explosion parameters for spruce biomass through experiments carried out using the 1m^3 explosion test vessel. It is suggested that given the relatively high lower explosive limit and guidance from recently issued papers that the size of external zones can be extremely small without any compromise in the safety of a system**.**

Keywords: Biomass, DSEAR, ATEX, Hazardous Area Classification

1. INTRODUCTION

Coal has traditionally been a cheap, reliable and safe fuel with a mature technology base. However, due to concerns over the emissions, European Legislation is limiting the number of hours that these stations can operate, with many closing in the near future. The Large Combustion Plant Directive (EC, 2012) is a European Union directive which aims to limits emissions from combustion plants with a thermal capacity of 50MW or greater. The main elements of the coal fleet (furnaces, boilers, turbines, alternators etc.) still have many years of service life remaining and so some operators are looking to either co –fire or exclusively use biomass to fuel the boilers.

Biomass is derived from organic materials, either specifically grown for use in combustion or the by-products of other processes (agriculture, paper and pulp, timber).

DSEAR defines a dangerous substance as one which has the potential to give rise to fires, explosions or other energetic events. (HSE, 2003). Biomass is therefore a dangerous substance and operators must comply with DSEAR.

The control of ignition sources is a key risk reduction measure, but one that comes after only a number of other safeguards must be considered. In regulation 7.1 of DSEAR, the requirement for classifying areas where a flammable atmosphere may occur into zones, is laid out as a statutory requirement. Therefore all operators of biomass facilities must undertake a hazardous area classification study (HAC).

In essence, with relation to biomass, an operator must segregate their facility into the following zones:-

Zone	Definition
20	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.
21	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.
22	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Table 1 Zone definitions (BSI, 2009)

Once these hazardous areas are identified, any equipment installed in them must be appropriately designed, constructed, certified and maintained (HMSO, 2001). Much of the judgement in assessing these zones is qualitative and open to wide variations depending on the person carrying out the study.

This view is underpinned by Eckhoff's (2006) paper reviewing the ATEX directives. He is critical of the lack of understanding of the differences between gas and dust explosion risks inherent in the standards and statutory regulations. Buschart (1997) echoes the view that the behaviour of dust is different to gases and that dust classification has not received an appropriate level of investigation.

It is the zoning of areas for biomass that this paper will consider. The objective of this work is to propose an approach that can assist in the Hazardous Area Classification (HAC) of facilities processing and handling biomass for thermal power generation.

2. METHODOLOGY

All the tests were carried out using the University of Leeds $1m^3$ explosion test vessel. The material tested was a spruce wood dust taken from a PowerStation dust extraction system. Following elemental analysis, it was established that the material had a stoichiometric concentration in air of $250g/m^3$.

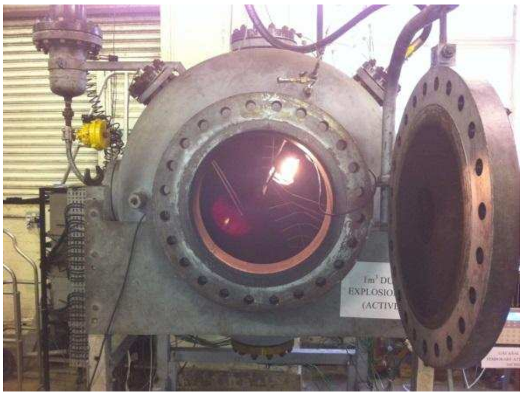
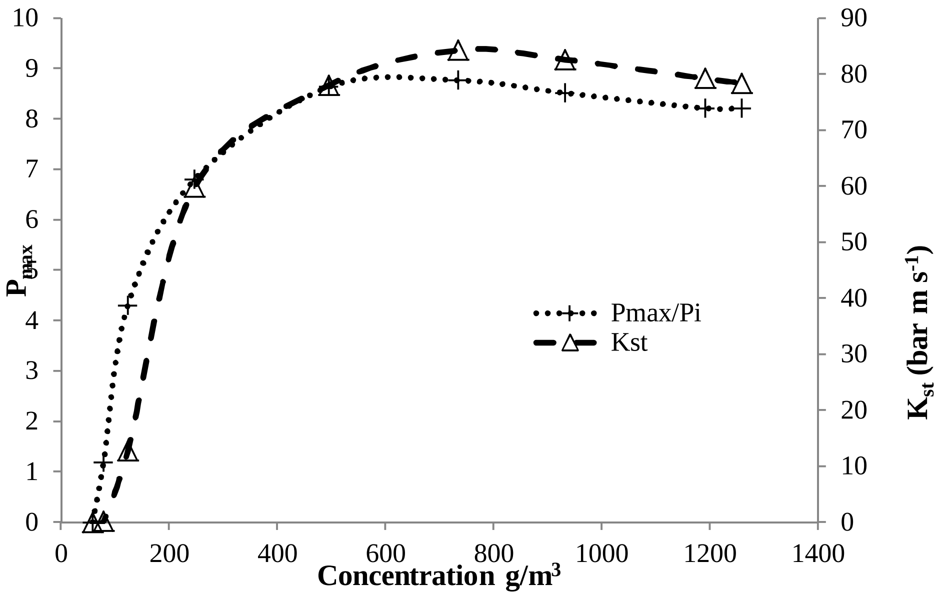


Figure 1 **The University of Leeds modified 1m^3 explosion test vessel**

As has been well described by Sattar et Al (2013), the vessel was modified from the design laid down in ISO 6184 and BS EN 14034 for biomass testing by having a larger injection pot (10L vs. 5L), a disperser sphere rather than a ‘C’ ring and a longer ignition delay.

3. RESULTS



The peak pressure ratio is approximately 8.8 at a concentration just above 600g/m^3. This is almost 3 times the theoretical stoichiometric ratio. The K_{st} remains high at high equivalence ratios and there is no significant reduction as the mixture becomes richer.

No over pressure was observed at 60g/m^3 but a slight pressure rise was observed at a nominal 80g/m^3 (90g of material injected). Although the rise of 0.19Bar is less than the 0.3Bar used as a benchmark in the standard, it was decided to use this concentration as the LEL for this material. It will be noted though that the overpressure at this level was low.

Using this relatively high (for a dust) LEL, implies that the generation of a flammable atmosphere outside of the containment of equipment would require a very extensive dust cloud and a large loss of containment.

4. DISCUSSION OF RESULTS

4.1 Comparison of Biomass results with Coal Dust

As many of the users of Biomass will be changing from processing and firing with coal or Pulverised Fuel (PF) to Biomass, it is useful to compare the findings for biomass against the results for ESB supplied coal tested under the same conditions using the same equipment.

Sample	**Bulk density (Kg/m^3)**	**Moisture (%)**	**A/F$_{mass}$**	**Stoich F/A (g/m^3)**
Coal	407.4	12.4	11.03	108.78
Spruce Biomass	250.9	8.2	6.63	181.06

Table 2 Comparison of tested biomass and coal dust properties

The first graphs plot the maximum overpressure measured for each fuel against concentration and equivalence ratio.

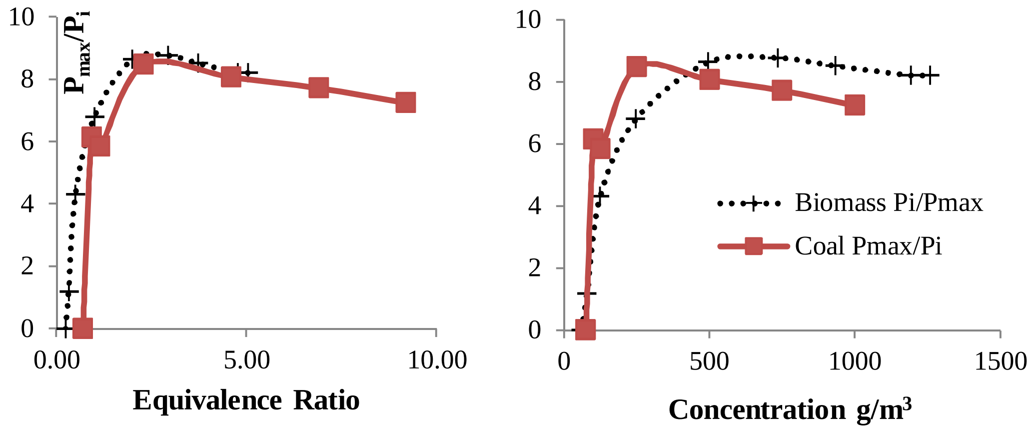


Figure 2 Graphs showing coal and biomass overpressure against equivalence ratio and concentration

When using equivalence ratio as the basis, the two materials behave in much the same way. When the overpressure is plotted against mass concentration, the measure more likely to be used in industry, it can be seen that the coal displays a more pronounced peak before subsiding whilst the explosion overpressure remains high for the richer mixtures.

Next, the K_{st} or volume independent peak explosion pressure rate rise for each material was plotted.

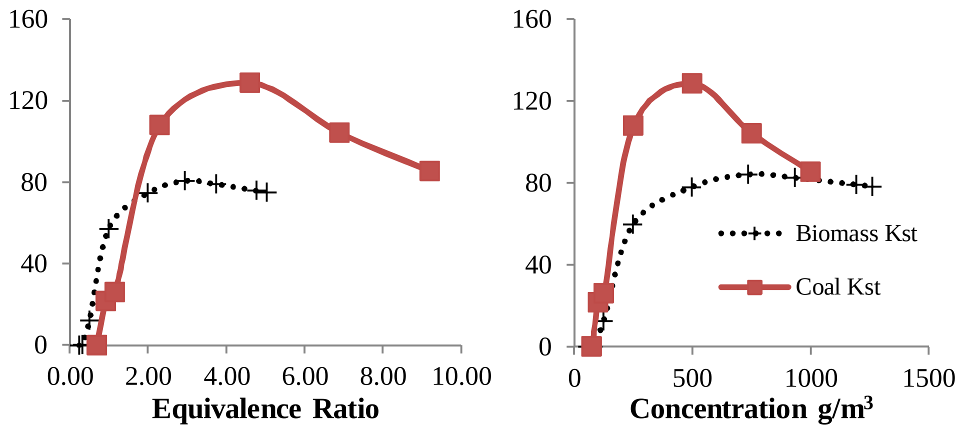


Figure 3 **Comparison of Coal and Biomass K_{st} Vs. Equivalence Ratio and concentration**

Here, the coal can be seen to be more volatile than the biomass with a more pronounced decay for the richer mixtures.

4.2 Application to Hazardous Area Classification

When classifying biomass processing buildings into zones, the guidance in IEC 60079-10-2, (2009) and the DSEAR ACOP L138 (2003) would drive an operator to classify large areas of buildings where biomass is handled as zone 22. This adds capital and revenue costs as well as requiring specialist inspection and maintenance routines for the life of the installed equipment.

The current guidance and standards appear to take the methodology used for gas and vapour zoning and relate this directly to dust. This view is held by Eckhoff (2000) who compares the standards that dust flammable area equipment is constructed to with the standards for gas equipment. For equipment to ignite a flammable dust cloud, the dust must either:-

- Settle on the apparatus and then ignite through an elevated surface temperature which takes a finite period of time and then ignite the still suspended dust cloud.
- Enter the apparatus through a gap, remain in the flammable region, be ignited through an electrical or mechanical spark or hot surface, explode and then again ignite an external dust cloud that must be in suspension

Both of these scenarios are credible inside dust handling equipment where additional safeguards must be taken to either prevent ignition sources becoming effective or mitigating the effect of explosion, as required by Regulation 6 of DSEAR. However, outside equipment, the presence of dust should not necessarily mean that there is an explosion risk.

In order for there to be an explosion risk, the dust must be in the flammable range. In general industry, there are tight controls over workplace dust levels, laid out in the Control of Substances Hazardous to Health Regulations. This limits the amount of inhalable dust that can be present in a work atmosphere to 10mg/m^3 (HSE, 2002).

Hence, in a well-managed workplace, which is typical of a PowerStation, it is highly unlikely that the level of aerated dust will exceed the LEL during normal operation, meaning an external zone 21 in the general building is not required.

The definition of a secondary release is taken from IEC 60079-10-2 and is, “release that is not expected to occur in normal operation and, if it does occur, is likely to do so only infrequently and for short periods. For example, a dust handling plant where deposits of dust are present.”. To further clarify this definition, IEC 60079010-2 goes on to state, “Consideration of major or catastrophic plant failures is not required in assessing potential sources of release.”

In practice, large dust clouds formed outside of equipment in the open air are formed by large failures of equipment, often after a primary explosion and result in secondary explosions. In carrying out the literature review, the only incidents found involving dust explosions outside of equipment were secondary explosions.

Dust fires are common but a primary explosion taking place in a building would appear to be exceedingly rare. Eckhoff reinforces this by stating that accumulations of dispersible dust should be controlled to prevent secondary explosions.

Lofted dust forming a cloud in the flammable range through smaller failures are unlikely to remain airborne long enough to be ignited in the open air, a view backed up by Eckhoff (2000).

So, with these factors in mind, it is suggested that the application of Zone 22 to external areas of a building be limited to those areas where a credible and foreseeable failure can give rise to an aerated dust cloud that will persist for longer than a few minutes. Certainly treating a pile of material as a source of release as required by DSEAR does not fit this definition.

Leaks from duct and pipe joints, equipment packed glands and rotary mechanical seals are unlikely to release enough material to enter the flammable range except right beside the source of the leak.

Of course, care must be taken to remove accumulations of dust and to keep the area as clean as possible but this would be to mitigate the effects of a secondary explosion. The ignition source for such an explosion is more than likely to be the flame front from the primary explosion but such an event certainly fits the criteria of a ‘catastrophic failure’ and so the zoning of such areas is not seen as an appropriate layer of protection.

5. Conclusions

The following conclusions were reached from interpreting the results and interrogating and collating the existing standards and new research.

It is suggested that it is difficult to enter the flammable region for biomass dust outside equipment without a catastrophic failure. The LEL of the tested biomass is quite high compared to other combustible dusts. In the open air, dust clouds entering the flammable region are rare and when they do occur, it is either the result of a primary explosion, a catastrophic failure or they are extremely transient.

A dust cloud can only be created by additional aeration of a deposit meaning that the way DSEAR treats a pile of material as a source of release is incorrect as it requires an external influence to get it airborne and into the flammable region. As described above, this would most likely be as the result of a catastrophic event, something that need not be considered in identifying the zone of an area (BSI, 2009).

Most un-certified equipment during normal operation installed in open plant areas should not ignite dust clouds, providing it is not extremely hot, has naked flames or open incendive sparks. Even when a dust cloud can be generated in the open air, the chance of an uncertified piece of apparatus being an effective ignition source is exceedingly low. The way that equipment ignites dust and gas is different and the protection concepts for gas are not applicable to dust. This is especially pertinent in the open air. For this reason, the rational for zoning large areas of open plant is not there and uncertified equipment, which do not have inherently strong ignition sources (open furnaces, hot surfaces, multi spark generating) could be used.

The UEL cannot be determined in the 1m^3 test vessel. Until the UEL can be determined, all mixture strengths at high equivalence ratios (>1) should be treated as being in the flammable region and classified accordingly based on the frequency that the region in entered.

The explosion strength of biomass does not reduce as the mixture becomes richer. This is an area that warrants further research. However, this cannot be carried out using the 1m^3 vessel due to the imitations in the injection of the low density, fibrous material. The Hartmann apparatus may be more appropriate for investigating the UEL for concentrations greater than 2000g/m^3.

6. Acknowledgements

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